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**RELATIONSHIPS AMONG GRIZZLY BEARS
ROADS, AND HABITAT IN THE SWAN
MOUNTAINS, MONTANA**

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RH: Grizzly Bears, Roads, and Habitat

RELATIONSHIPS AMONG GRIZZLY BEARS, ROADS, AND HABITAT IN THE SWAN MOUNTAINS, MONTANA

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INTRODUCTION

Grizzly bear recovery programs in the western United States can be classified by 2 broad management goals. The first is based on managing population size to increase the numbers of grizzly bears within designated recovery areas. The second program is one of habitat management for the species. The fundamental goal of habitat management, is to maintain or improve habitat conditions that allow grizzly bears to obtain life requisites including spacial needs, security, and energetics.

One of the largest recovery areas is the Northern Continental Divide Ecosystem (NCDE) located in western Montana. The NCDE is comprised of national park lands (Glacier National Park), congressionally designated wilderness (Bob Marshall, Great Bear, Scapegoat, and Mission Mountain wilderness areas),

corporate lands, private lands, tribal lands, and non-wilderness national forests.

The non-wilderness national forest lands within the NCDE are managed under a multiple-use strategy. Grizzly bears living in this multiple-use environment contend with human recreation activities including hunting activities, and with timber harvest including road development. Timber harvest has served to change the pattern and composition of habitats and roads provided humans access to previously remote habitat. It is almost certain that these modified habitats, as well as legal and illegal mortalities, have altered the behavior patterns and demographics of the grizzly bear population. Published information and our understanding of grizzly bear habitat selection in multiple-use environments is minimal.

OBJECTIVES

We modeled the relationships between grizzly bears, roads, and habitat using multivariate techniques in conjunction with geographical information system (GIS) map layers (Pereira and Itami 1991). These relationships were evaluated relative to random expectation at 3 orders of resource selection (Johnson 1980). We first compared the habitat and road features within the composite multi-year annual home range of radio-collared female grizzly bears relative to habitats outside of the home range (second-order selection). Second, we compared habitat use derived from telemetry locations within the seasonal home ranges of individual female grizzly bears to random expectation (third-

order selection). Finally, we explored the spatial relationships among females and roads when bears ventured to within 500 m of a road (fourth-order selection).

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STUDY AREA

The study area was located in the Swan Mountain Range of western Montana (Fig. 1). The 1,457 km² area was bounded on the east by Hungry Horse Reservoir and on the west by the edge of contiguous forest cover in the Flathead River and Swan River valleys. The southern boundary was the border of the Bob Marshall Wilderness.

The study area was composed of private, corporate, state, and federal lands. Private lands were (9% of area) were situated in the Flathead Valley east of the city of Kalispell and a portion of the Swan River Valley. Most private tracts were

developed as permanent residences, farms, schools, and service facilities. Through ground reconnaissance and aerial photographic interpretation, we identified over 640 such structures on private land within the study area.

State, corporate, and federal lands were managed under a multiple-use philosophy. Multiple-use lands were managed primarily for timber harvest, recreation, and wildlife values. Land management policies for the federal, state, and corporate lands were in some cases dissimilar.

Beginning in the early 1950's, a network of high-quality roads was established on multiple-use lands primarily to access timber reserves and to construct Hungry Horse Reservoir. The Reservoir, completed in 1953, inundated 9712 ha of riparian and upland habitat (Casey et al. 1984). Two gravel roads, bordering the west and east side of the Reservoir provide direct access to the study area and a network of roads is present in most drainages.

The USDA Forest Service, Montana Department of State Lands, and corporate land-owners began closing roads to public access in the early 1980's to improve wildlife security and to protect other resource values, although a more aggressive closure program did not begin until approximately 1990. Road closure was achieved by various methods including gating, berming and reclamation. At present, there are 1962 km of roads in the study not reclaimed by natural vegetation. In 1990, the beginning of this investigation, 54% of the roads were continuously open to

public travel by vehicle. The remaining 909 km were either permanently or seasonally closed to vehicular travel by the public. Illegal vehicular travel on closed roads was known to occur in the study area, and there were no restrictions to people traveling on foot, bicycles, or horses.

METHODS

Capture

Grizzly bears were captured and radio-collared as described by Mace et al. (1994). Trap-site transmitters (Telonics, 932 Impala Ave. Mesa, AZ 85204-6699) were used selectively when snaring behind closed roads. Adults were those animals ≥ 5 years old with the exception of 1 female who matured at 4 years.

Grizzly Bear Relocations

Between 1990 and 1994, radio-collared grizzly bears were relocated from an aircraft during daylight hours using either a Cessna 172 or 180. Most relocations were obtained during morning, as flight conditions deteriorated as air temperatures increased. We photographed each relocation with a polaroid camera from the aircraft. The photograph developed immediately and enabled us to accurately record the bears' location. Using these photographs, color aerial photographs, and 1:24,000 orthophotographic quadrangles, we assigned a universal transverse mercator (UTM) coordinate to each relocation.

Only the most accurate aerial relocations were utilized. We documented an average aerial telemetry error of 150 m². This error was incorporated into each GIS map used for analysis using

a "moving window" GIS routine.

Seasonal Foraging Categories

We used 3 categories to describe the seasonal relationships among grizzly bears, roads, and habitat features. Categories were established from 6 data sources: 1.) major shifts in primary food plants eaten by grizzly bears as determined by scats collected opportunistically, and investigations at foraging sites 2.) published literature on food habits (Craighead et al. 1982, Mace and Jonkel 1983), 3.) visual observations of grizzly bear foraging behavior during telemetry flights, 4.) observed shifts in grizzly bear use of habitats, 5.) observed dates of den entry and exit during autumn and early spring, and 6.) the availability of snow-free habitats. Spring was defined as that period from den exit to 15 July. Summer was defined as 16 July to 15 September, and autumn from 16 September until den entry.

Home Range Estimates

The adaptive kernel method (Worton 1989) was used to estimate home ranges for individual female grizzly bears using the program CALHOME (U.S. Dept. Agri. Forest Serv. Pacific Southwest Forest Experimental Station. 2081 East Sierra, Fresno CA 93701). To investigate second-order selection, we constructed 95%, multi-annual home ranges for each individual. These ranges were then mosaiced together to form a composite female home range polygon.

Third-order selection was investigated using 100% seasonal home ranges. We did not construct home ranges for individual

grizzly bears having < 15 telemetry coordinates per season. Home range size and telemetry sample size per individual female are given in Table 1.

Road and Habitat Variables

Spatial relationships among telemetric locations of female grizzly bears, roads, and habitat were evaluated using GIS software (EPPL7, Minnesota Planning Office) and Erdas (Erdas, Inc. 2801 Buford Highway, NE. Atlanta, GA 30329-2137). All maps were built in a raster (pixel) format with a cell size of 30m². Details of mapping protocol for each map layer were as follows:

Road Maps We sought to describe the spacial distribution of roads, and spatial and temporal differences in use of roads by humans in vehicles. The spatial network of roads was described using road density (Mech et al. 1988) and distance to roads (Mattson et al. 1986, McLellan and Shackelton 1988). Levels of vehicular use were ascertained from magnetic traffic counters. Our field methods and mapping processes for roads were as follows.

All roads in the study area during 1990 were digitized from 1:24,000 orthophoto quads. We used forest travel plan maps, high elevation photography, and field reconnaissance to verify locations of roads. Each segment was initially categorized as either a highway, or primary, secondary, or tertiary gravel road. Each road was further classified as being open to vehicular traffic by the public, or closed to travel during each season via a gate or other obstruction. We did not map old roads that had

been reclaimed by natural vegetation or temporary "skid roads" in timber harvest units.

Levels of vehicular traffic We used magnetic counters to quantify levels of vehicular traffic on a sample of primary and secondary gravel roads. We placed counters within the study area during 1990-92 to provide information on the spatial and temporal patterns of human use (Fig. 1).

Four counters were placed on the West-side Road, between Hungry Horse Dam and Spotted Bear Ranger Station. Counter 1 was located approximately 5 km south of the Dam. Counters 2-3 were placed proximal to each other and mid-way between the Dam and the Station. Counter 4 was located approximately 68 km south of the Dam.

Counter 5 was located along a secondary gravel road at the extreme southern end of the study area that provided direct access to trails into the Bob Marshall Wilderness. We used 2 counters (numbers 6 and 7) on secondary gravel roads that bifurcated from the West-side road and were central to the study area. We sampled 2 secondary gravel roads (counters 8-9) near the Flathead Valley that could be directly accessed from highway 35 and a paved country road. And finally, counter 10 was located on a gravel road leading from the Flathead Valley to a popular hiking area in the study area.

Average daily traffic (ADT) volumes were calculated from vehicle counts at these 10 counters and summarized by season (Table 2). ADT values revealed substantial spacial and temporal

variation and were therefore converted to 5 broad classes: 1= 0 vehicles/day, 2=1-10 vehicles/day, 3= 10-60 vehicles/day, 4= 60-300 vehicles/day, and 5= >300 vehicles/day. We then coded and mapped all roads in the study area by these classes for each season, based on their proximity to roads with counters and whether they were open to vehicular travel. We calculated the distance to roads of each traffic class in 30 m increments (maps CLAS1-CLAS5). Using the "moving window" GIS routine, we calculated the average distance to a road within the telemetry error polygon.

Road Density The linear road map was converted to a total road density map using a moving circle with a radius of 570 m (19 pixels) (ERDAS). Because of the pixel size of GIS maps (30 m²), we were able to only approximate km of road/km². Total road density (map TOTRD) was a continuous variable and classified in increments of 30 m of road/km². Areas with a TOTRD of 0 km/km² were termed "unroaded." Again, the average road density within the telemetry error polygon was calculated.

In summary, the spatial distribution of roads was expressed as road density and distance. Vehicular use was expressed as ADT classes. Each GIS pixel in the study area was then described by road density and distance to each class of vehicular use that contributed to that road density.

Vegetation Zones: Using field reconnaissance data and an elevation DEM (CITEXXXX), the study area was categorized into 3 vegetation zones depicting dominant coniferous trees (Craighead

et al. 1988). The low temperate zone (LOTEMP) extended from 870 m to the lower limit of subalpine fir (Abies lasiocarpa) at (1494 m) and constituted 43% of the study area. The temperate zone (TEMP) extended to the upper limit of Douglas fir (Pseudotsuga menziesii) and western larch (Larix occidentalis) at (1981 m) (45% of study area). Habitats above 1981 m were classified as the subalpine zone (SUBALP). There was little if any true alpine flora in the study area (Mace et al. 1994).

HABITAT MAP: A broad habitat map was constructed by superimposing several habitat features upon satellite imagery. A 28 August 1988 Thematic Mapper image was classified to 30 spectral classes using an unsupervised routine (Manley et al. 1992), tasseled-cap transformation (Crist and Cicone 1984), and a limited shadow correction. The vegetative characteristics of these 30 interim classes were initially characterized from field reconnaissance. Photographic interpretation was then used to further refine accuracy of the image. A 30x9 spectral class and aspect matrix was constructed. For each matrix cell, a minimum of 5 coordinates (n= 1600) was assigned to 1 of 3 cover types: nonvegetated/grass-forb land (NONGRAS), shrub-land (SHRUB), and forested areas (> 40% overstory canopy of conifers) (FOREST). We then overlaid 4 digitized habitat features (Mace 1985) that were considered of interest to land management; avalanche chutes (CHUTE), slabrock (SLAB) (Mace 1985), and timber harvest units (CUT). Slabrock was defined as exposed and terraced slabs of glacially-scoured bedrock with intervening vegetation and

occurred within the TEMP and SUBALP zones. The timber harvest map included all overstory removal methods.

Using the moving window GIS routine we mapped the dominant habitat within the telemetry error polygon. Lakes and those habitats screened by shadow were identified and omitted from the final habitat map.

ASPECT MAP Five aspect categories were developed from DEMs. These were: northwest-northeast (NWNE, 315-45°), northeast-southeast (NESW, 46-135°), southeast-southwest (SESW, 136-225°, southwest-northwest (SWNW, 226-314°), and flat.

LAND OWNERSHIP We divided the study area into 2 geographical areas based on land-ownership and predominant land-use patterns, and termed these the private and multiple-use zones. This dichotomous variable was coded 1 for multiple-use lands and 0 for private lands.

Model Building Strategies and Statistical Methods:

Our model building strategy varied by objective. For second-order selection, 4,668 random points within the composite female home range were compared to 2,447 random points outside of the range. For selection within seasonal home ranges, telemetry points from female grizzly bears were compared again to random expectation.

We used logistic regression (maximum likelihood estimates) to evaluate the relationships between female grizzly bears, roads, and habitat features. Logistic regression was chosen because variables were a mixture of continuous and categorical

data (Press and Wilson 1978).

For second-order selection, our model building strategy was as follows. Random coordinates were coded 1 if they occurred within the composite female home range and 0 for those occurring outside the range. We first investigated univariate significance of TOTRD, cover types, and aspect class variables using logistic regression. Each variable was modeled individually, and importance of those variables was ascertained by comparing the log-likelihood X^2 value against the X^2 value in the "no selection model" (Hosmer and Lemeshow 1989, Manly et al. 1993). Variables that were significant ($p \leq .25$) were then entered into an initial multivariate model, termed the "full model." For categorical variables, all variables were maintained in the model if only 1 was significant. The importance (p value) of each variable in the full model was determined again by the log-likelihood ratio test. Variables that contributed little ($p \leq .10$) to the full model were omitted and a second reduced model was constructed. Variable coefficients and their standard deviations were calculated. Statistical analyses were conducted using STATISTICA (Statsoft Inc. 2325 East 13th. St. Tulsa, OK 74104).

For second-order analyses, we calculated resource selection functions (RSF) (Manley et al 1993, p. 126). RSF values represented the relative probability of a unique habitat and road combination occurring within the composite female home range, and was scaled from 0-1.0.

To investigate relationships among variables within seasonal

home ranges (third order), random points were compared to telemetry points obtained from individual female grizzly bears. Logistic regression was again used to investigate univariate significant of TOTRD, cover type, and aspect variables. Variables showing univariate significance of $<.25$ were entered into a multivariate logistic regression model. Our goal was not to construct as parsimonious model as possible, rather to compare and contrast the significance and coefficient strength (positive or negative association) of variables among individuals.

Fourth order selection was evaluated in areas within a 500 m buffer surrounding roads within each females' home range. Multivariate tests were not conducted at this level of selection because of limited telemetry samples size. Within the roaded buffer we compared telemetry and random points relative to TOTRD and distance to the nearest road for each of the 5 ADT classes. Road density and distance measures were then pooled. Comparisons were made using Pearsons' chi-squared statistic.

RESULTS

Second-order Selection:

The composite female home range (Fig. 1), constructed from 14 individual female grizzly bear annual ranges, differed from the area outside of the range for all map layers. Female grizzly bears confined their activity entirely to multiple-use lands (OWN) within the study area and did not utilize habitats on private property. Conversely, 25% of the non-range area was private property (Table 3).

The composite range had a greater proportion of TEMP (55%) and SUBALP (15%) habitats relative to the area outside the range (Table 3). The LOTEMP zone comprised 31% of the composite range compared to 71% outside of the range. These differences in composition relative to vegetation zone were univariately significant ($\chi^2 = 1052$, $df = 2$, $p = .00$).

The composite home range differed significantly from the non-range relative to cover types ($\chi^2=147$ $df= 5$ $p= .00$). The composite range was less forested (FOREST), and had greater amount of the variables CHUTE, NONGRAS, and SLAB (Table 3). The proportion of habitat converted through timber harvest (CUT) was similar between the 2 areas.

The mean total road density (TOTRD) was lower within the composite range ($x=0.6$ km/km²) than outside ($x= 1.1$ km/km²). The cumulative frequency graph (Fig. 2) revealed the differences between areas. Fifty-six percent of the composite range was unroaded (0 km/km²) compared to 30% outside the range.

Roads were not equally distributed among vegetation zones. The LOTEMP zone comprised 43% of the study area and contained 84% of the roads. The remaining 16% of the roads were located in the TEMP zone (45% of area).

There was little difference between composite range and non-range relative to distance to CLAS1 AND CLAS3 roads (Table 3). Roads having these 2 vehicle use levels were distributed similarly throughout both areas. The average distance to a CLAS1 road for both areas was < 2 km, while for a CLAS3 road the

average was between 7-8 kms. Within the composite range, the maximum distance from a CLAS1 road a female could achieve was 5.3 km's.

Habitats within the composite range were closer to CLAS2 roads than those habitats outside the range; these differences were significant (t df p). Nineteen percent of the composite home range was within 1 km of a CLAS2 road (Fig. cc)

The composite range was not closely associated with either CLAS4 or CLAS5 roads. Although there were habitats in the range within 0.03 km of a CLAS4 road, the mean distance was 21.3 km. There were no habitats within the composite range within 0.51 km of a CLAS5 road.

Logistic regression revealed the strength and relationship among variables at the second order of selection. The final logistic model was given by the following equation:

$$w^*(x) = \exp \{ \log_e (P_u/P_v) - 5.098 - .371(\text{TOTRD}) - .245(\text{CLAS2}) + .538(\text{CLAS3}) - .149(\text{CLAS4}) + .475(\text{CLAS5}) - 2.649(\text{LOTEMP}) - 1.075(\text{TEMP}) + 4.049(\text{OWN}) - .105(\text{NONAGRI}) + .590(\text{SHRUB}) + 1.545(\text{SLAB}) - .275(\text{CUT}) \}$$

$$\frac{1 + \exp(\log_e (P_u/P_v) - 5.098 - .371(\text{TOTRD}) - .245(\text{CLAS2}) + .538(\text{CLAS3}) - .149(\text{CLAS4}) + .475(\text{CLAS5}) - 2.649(\text{LOTEMP}) - 1.075(\text{TEMP}) + 4.049(\text{OWN}) - .105(\text{NONAGRI}) + .590(\text{SHRUB}) + 1.545(\text{SLAB}) - .275(\text{CUT}))}{1 + \exp(\log_e (P_u/P_v) - 5.098 - .371(\text{TOTRD}) - .245(\text{CLAS2}) + .538(\text{CLAS3}) - .149(\text{CLAS4}) + .475(\text{CLAS5}) - 2.649(\text{LOTEMP}) - 1.075(\text{TEMP}) + 4.049(\text{OWN}) - .105(\text{NONAGRI}) + .590(\text{SHRUB}) + 1.545(\text{SLAB}) - .275(\text{CUT}))}$$

where P_u/P_v is the sampling fraction equaling 1.91.

The composite range was positively associated with multiple-use lands (Table 3). RSF values were zero for all combinations of habitat and road variables on private property.

Coefficients were negative for the LOWTEMP and TEMP vegetation zones. The largest RSF values were achieved for the SUBALP zone (Fig 3).

SLAB, CHUTE, and SHRUB were the most discriminating cover type variables. The composite home range was positively associated with these 3 types. Under certain variable combinations, higher RSF values were achieved for CHUTE relative to the other types (Fig. 4).

The female composite home range was negatively associated with increase values of TOTRD. RSF values ranged from 0 to 1.0 for unroaded habitats (0 km/km²). When TOTRD exceeded 0 km/km², RSF values dropped below 30% (Fig. 5). There was no selection value (RSF=0) when TOTRD exceeded 3 km/km².

Distance to CLAS1 roads did not enter into the multivariate logistic regression. RSF values for distance to the remaining 4 road classes confirmed the univariate statistics for these variables. Larger RSF values for CLAS2 roads were observed at distances > 0 and less than 10 km. RSF values for CLAS3-5 increased with distance.

SPRING:

Third-Order Selection

We compared telemetry locations to random expectation relative to road and habitat features within the 100% home ranges of 10 females during spring.

We could not pool individuals because the available habitat and road features was variable. The 10 seasonal ranges varied in

the availability of vegetation zones (Fig. 6). Female home ranges were situated primarily in the TEMP zone. The proportion of range's in the LOTEMP and SUBALP zones varied from 22-47% and 6-26% respectively.

All home ranges were dominated by the FOREST cover type (Fig. 6). The amount of past timber harvest activity (CUT) in the ranges varied between 6-26%. Cover types NONGRAS and SLAB were rare within ranges relative to other cover types. The proportion of CHUTES within ranges varied between 4-10%.

Dominant aspect varied among ranges (Fig.6). Category NESW predominated in all ranges, and category FLAT was rare relative to other aspects.

The amount of unroaded habitat varied by bear from 44 to 64% (Fig. 6). Eight of 10 home ranges did not contain any CLAS4 or CLAS5 roads.

Univariate logistic regression confirmed the variability in habitat availability and selection among individuals (Table 4). During spring, most female grizzly bears were negatively associated with the LOTEMP and SUBALP zones and positively associated with the TEMP zone.

Although all ranges had high proportionate coverage of FOREST, coefficients for this cover-type were negative for 8 of 10 bears. All females exhibited significant positive selection for CHUTES (Table 4).

Eight of 10 individuals exhibited a negative coefficient for TOTRD; 7 were significant ($p < .25$). Two females exhibited a

significantly positive relationship to TOTRD.

Multivariate relationships among habitat and road variables were less conclusive than univariate statistics. A significantly positive selection for the cover type CHUTE was evident for all bears (Table 4). Coefficients for TOTRD were nonsignificant ($p < .10$) for 5 of 10 bears; 2 individuals exhibited a significant negative coefficient and 1 bear a positive relationship.

Dominant aspect entered into multivariate analyses for 9 of 10 bears. Aspect did not appear to be important in multivariate models of female grizzly bears during spring. Although not significantly important, the SWNW aspect was positive for 7 of 9 bears.

Forth Order Selection

While within 500 m of a road during spring, 8 of 10 female grizzly bears were in habitats with significantly lower ($p < .10$) TOTRD than random expectation (Table 5). The 2 individuals using higher TOTRD areas were not significantly different from random. Average TOTRD varied among individuals from 0.6 to 2.2 km/km². When individuals were pooled, the average TOTRD was 1.3 km/km².

Seven of 10 females were at further distances from a CLAS1 road, 5 of which were significant (Table 5). Two females were nearer to CLAS1 roads than random but differences were not significant. When individuals were pooled, the average distance to a CLAS1 road within the 500 m buffer was 250 m compared to 200 m for random points.

All females had CLAS2 roads within their spring home range.

Four of 10 bears had <5 telemetry points within 500 m of a CLAS2 road. The remaining 6 individuals were all further from a road of this use level than random. When pooled, female grizzly bears averaged 280 m from a CLAS2 road (Table 5).

Seven individuals had CLAS3 roads within their home range. Only 1 bear (Number 147) had > 5 locations within 500 m of this road class (n=15 locations). The other 6 bears rarely used habitats near CLAS3 roads. Most females did not have CLAS4-5 roads within their ranges. The 2 bears that did, exhibited no telemetry points within 500 m (Table 5).

SUMMER

Third Order Selection

Fourth Order Selection

AUTUMN

Third Order Selection

Fourth Order Selection

DEMOGRAPHIC CONSEQUENCES OF ROADS

DISCUSSION

TOPICS TO DISCUSS:

1. chose total rd because of road closures during study, levels of use did not change by gate status did
2. why 95% composite. because of far ranging ability of g.b., 100% annual ranges inflated beyond what field observations suggest. by using 95%, we were more sure to capture most hr extent. Also, by using mosaiced hrs, we were actually including more than 95% of some internal bears, their 100 was captured

because of overlap

3. goal was not to build the most parsimonious model, rather to explain the relative strength of road and habitat variables
4. data represents those bears that survived long enough to obtain adequate sample size for telemetry pnts. could not analyze 3 females because they were man-caused deaths before adequate sample..all three deaths were related to human access and sanitation.
5. why chose 100% seasonal ranges.... provide full range of availability relative to roads. core area would be more meaningful, but would have sacrificed sample size of pnts.
6. Number 147 habituated and removed from area
7. why no male analysis. we were unable to have male logistic regressions converge...could not be modeled on available variables. large home ranges, appear to move in response to factors other than food. probable that males would have to be monitored at 3-4 times the intensity of females to understand relationships.

LITERATURE CITED

- Archibald, W. R. R. Ellis, A. N. Hamilton. 1986. Responses of grizzly bears to logging truck traffic in the Kimsquit River Valley, British Columbia. Int. Conf. Bear. Res. and Manage. 7:251:257.
- Belden, R. C. and B. W. Hagedorn. 1993. Feasibility of

- translocating panthers into northern Florida. J. Wildl. Manage. 57(2):388-397.
- Casey, D., C. A. Yde, A. Olsen. 1984. Wildlife impact assessment and summary of previous mitigation related to hydroelectric projects in Montana. Vol. 3. Hungry Horse project. MT. Dept. Fish, Wildl., and Parks. Kalispell, MT.
- Chou, Y, and R. A. Minnich. 1990. Spatial autocorrelation of wildfire distribution in the Idyllwild Quadrangle, San Jacinto Mountain, California. Photogrammetric Eng. and Remote. Sensing. 56(11):1507-1513.
- Cliff, A. D. and J.K. Ord. 1981. Spatial Processes: Models and applications. Pion Press, London. 266pp.
- Craighead, J. J., J. S. Sumner, G. B. Scaggs. 1982. A definitive system for analysis of grizzly bear habitat and other wilderness resources. Wildlife-Wildlands Inst. Monogr. No. 1. Univ. Montana Foundation, Missoula, MT 279pp.
- Crist, E. P., and R. C. Cicone. 1984. Application of the tasseled-cap concept to simulated thematic mapper data. Photogr. Eng. Remote Sens. 50:343-352.
- Haining, R. 1980. Spatial autocorrelation problems. Geography and the Urban Environment. (D. Herbert and R. Johnson eds.) Vol. 3 pp. 1-43.
- Hosmer, D. W. and S. Lemeshow. 1989. Applied logistic regression. John Wiley and Sons. 307 pp.
- Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluation of resource preference. Ecol.

61:65-71.

Kasworm, W. F. and T. L. Manley. 1989. Road and trail influences on grizzly bears and black bears in northwest Montana. Int. Conf. Bear Res. and Manage. 8:79:84.

Lyon, L. J. 1979. Habitat effectiveness for elk as influenced by roads and cover. J. For. 77:658-660.

Lyon, J.G., J.T. Heinen. R.A. Mead, and N.E. Roller, 1987.

Spacial data for modeling wildlife habitat. J. of Surveying engineering. 113(2): 88-100.

Mace, R. D. and C. J. Jonkel. 1983. Regional Food habits of grizzly bears in Montana. xxxxxxxxxxxxxxxx

_____, 1985. Analysis of grizzly bear habitat in the Bob Marshall Wilderness, Montana. USDA For Serv. Gen. Tech Rept. INT-207. pp. 136-149.

_____, S. C. Minta, T. L. Manley, and K. E. Aune. 1994. Estimating grizzly bear population size using camera sightings. Wildl. Soc. Bull. 22:73-84.

Manly, B. F., L. L. McDonald, D. L. Thomas. 1993. Resource selection by animals. Statistical design and analysis for field studies. Chapman and Hall. 177pp.

Manley, T. L., K. Ake, and R. D. Mace. 1992. Mapping grizzly bear habitat using Landsat TM satellite imagery. Pp. 231-240 in: Remote Sensing and Natural Resource Management. Proc. 4th. Forest Service Remote Sensing Applications Conference.

Mattson, D. J., R. H. Knight, and B. M. Blanchard. 1986. The effects of developments and primary roads on grizzly bear

habitat use in Yellowstone National Park, Wyoming. Int. Conf. Bear Res. and Manage. 7:259-273.

_____. 1989. Human impacts on bear habitat use. Int. Conf. Bear Res. and Manage. 8:33:56.

McLellan, B. N. and D. M. Shackleton. 1988. Grizzly bears and resource-extraction industries: effects of roads on behaviour, habitat use and demography. Journ. App. Ecol. 25:451-460.

Mech, L. D., S. H. Fritts, G. L. Radde, W. J. Paul. 1988. Wolf distribution and road density in Minnesota. Wildl. Soc. Bull. 16:85-87.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. Am. Midl. Nat. 37:223-249.

Pereira, J. M. and R. M. Itami. 1991. GIS-based habitat modeling using logistic multiple regression: a study of the Mt. Graham red squirrel. Photogrammetric Engineering and Remote Sensing. 57(11):1475-1486.

Press, S. J. and S W. Wilson 1978. Choosing between logistic regression and discriminant analysis. J. Am. Stat. Ass. 73:699-705.

Thurber, J. M., R. O. Peterson, T. D. Drummer, S. A. Thomsama. 1994. Gray wolf response to refuge boundaries and roads in Alaska. Wildl. Soc. Bull. 22:61-68.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecol. 70(1):164-168.

Wrigley, N. 1976. An introduction to the use of logit models in

geography. Concepts and techniques in modern geography. 10

Geo Abstracts, Norwich.

Zager, P. E. 1980. The influence of logging and wildfire on
grizzly bear habitat in northwestern Montana. Ph.D. thesis,
Univ. Montana, Missoula.

Table 1. Seasonal Home range Size and telemetry sample size for female grizzly bears, Swan Mountains, Montana.

Bear Number	Age ^a	Seasonal Telemetry Sample Size (Home Range Size, km ²)			
		Number Years Monitored	Spring	Summer	Autumn
3	4	2	16 (311)		
5	10	3	58 (380)		
	3	4	49 (137)		
45	19	4	76 (302)		
48	10	4	80 (136)		
94	10	3	52 (225)		
96	17	4	83 (198)		
137	3	3	39 (169)		
143	7	2	19 (156)		
147	4	3	52 (578)		

^a age during first year of telemetry sample.

Table 2. Summary of average daily traffic from 10 traffic counters within the study area (mean, SD, n days monitored).

Counter number	Average daily traffic volume statistics by season			
	Early spring	Spring	Summer	Autumn
1	85, 110, 123	311, 171, 130	471, 207, 135	97, 54, 122
2-3	57, 50, 10	31, 36, 27	32, 15, 62	8, 8, 76
4	13, 19, 112	32, 21, 109	57, 21, 136	26, 20, 152
5	8, 9, 76	7, 7, 90	10, 8, 123	10, 7, 152
6-7	4, 6, 163	3, 3, 183	6, 5, 272	7, 9, 348
8-9	10, 9, 244	15, 22, 180	22, 18, 249	22, 19, 302
10	15, 15, 183	50, 31, 135	70, 34, 186	25, 20, 178

Table 3 Summary statistics and results of multivariate logistic regression at second-order of selection where the composite female home range compared to area outside of home range. Swan Mountains, Montana.

Road-Habitat Variable	Univariate Statistics								Multivariate Statistics (Final Model)		
	Within 95% Home Range				Outside 95% Home Range						
	Minimum-maximum	Mean	S.E.	% ^b	Minimum-maximum	Mean	S.E.	%	Coefficient	S.E.	P
TOTRD (km/km ²)	0 - 6.3	0.6	.014		0 - 5.2	1.1	.022		-0.371	.050	.00
DIS1 (km)	0 - 5.3	1.2	.014		.03 - 7.4	1.5	.031		na ^d		
DIS2 (km)	.03 - 18.2	4.6	.055		.03 - 30.2	14.2	.134		-0.245	.010	.00
DIS3 (km)	.03 - 21.9	7.1	.077		.03 - 25.0	8.0	.135		0.538	.029	.00
DIS4 (km)	.03 - 44.4	21.3	.184		.03 - 39.0	13.3	.195		-0.149	.011	.00
DIS5 (km)	.51 - 30.7	13.1	.089		.03 - 29.0	5.0	.109		0.475	.024	.00
NONGRAS				3				4	-0.105	.349	.763
SHRUB				14				10	0.590	.156	.00
FOREST ^a				59				67			
WETLAND ^a				7				2	0.786	.283	.004
SLAB				2				0.2	1.545	.840	.065
CUT				15				17	-0.275	.124	.026
LOTEMP				31				71	-2.649	.286	.000
TEMP				55				24	-1.075	.275	.000
SUBALP ^a				15				5			
OWN				100 ^c				75 ^c	4.049	.592	.000
LOTEMPxTOTRD									na ^d		

^a design variables

^b percent of total for categorical variables

^c percent multiple-use lands

^d non significant in univariate logistic regression

Table 4. Summary of logistic regression coefficients for female home ranges during the early spring-spring season. N=10 ranges

Variable	Number of Ranges having Positive or Negative Logistic Regression Coefficients (Number of Significant Ranges)			
	Univariate ^a Analysis		Multivariate ^b Analysis	
	Negative	Positive	Negative	Positive
LOTEMP	7 (4)	3 (2)	0	10 (6)
TEMP	2 (2)	8 (7)	0	10 (7)
SUBALP ^c	9 (8)	1 (0)		
CHUTE	0	10 (10)		10 (10)
SHRUB	8 (4)	2 (0)	6 (2)	4 (1)
FOREST ^c	8 (7)	2 (0)		
SLAB	7 (4)	2 (2)	7 (0)	2 (2)
CUT	10 (7)		6 (0)	4 (1)
NONGRAS	7 (3)	3 (0)	7 (1)	3 (0)
FLAT ^c	8 (2)	2 (2)		
NWNE	8 (6)	2 (0)	3 (0)	6 (0)
NESE	7 (4)	3 (3)	4 (1)	5 (1)
SESW	3 (1)	6 (5)	3 (0)	6 (1)
SWNW	5 (4)	5 (3)	2 (0)	7 (0)
TOTRD	8 (7)	2 (2)	6 (2)	4 (1)
LOTEMPXTOTRD	9 (5)	1 (1)	5 (5)	1 (1)

^a p < .25^b p < .10^c design variables

Table 5. Forth order Selection of female grizzly bears relative to total road density and distance to closest road. Analyses were confined to within 0.5 km of a road. Swan Mountains, Montana.

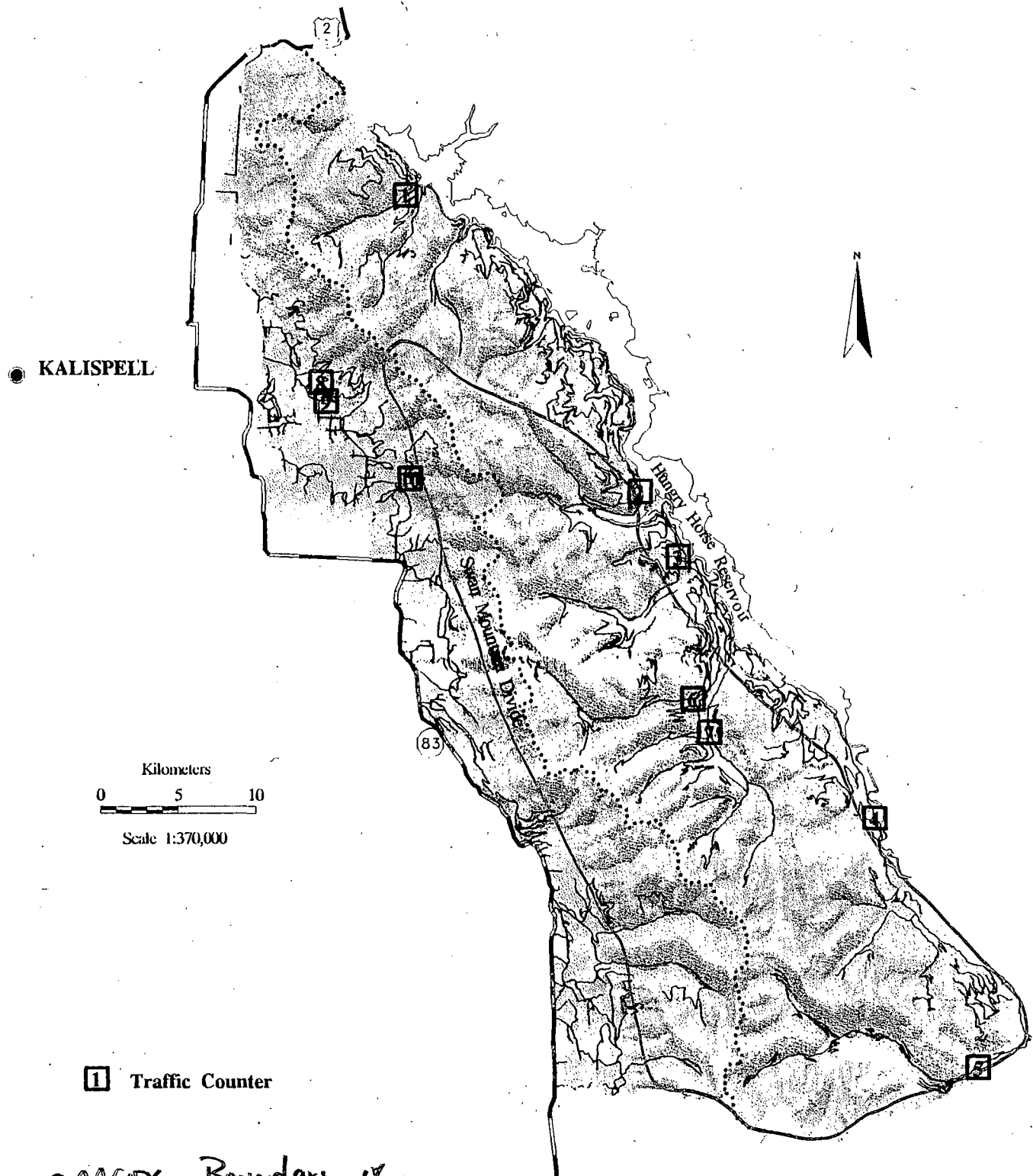
Bear Number	Av. Total Road Density (km/km ²)	Av. Distance (m) To Road for Telemetry and Random Points (p value)				
		Class 1	Class 2	Class 3	Class 4	Class 5
3	0.6, 1.3 (.02)	360, 220 (.01)	x ^a	na ^b	na	na
5	2.2, 1.9 (.15)	160, 170 (.69)	x	x	na	na
18	0.8, 1.6 (.00)	250, 190 (.12)	480, 180 (.04)	x	na	na
45	0.8, 1.6 (.03)	300, 210 (.05)	xx ^c	na	na	na
48	0.9, 1.5 (.00)	300, 210 (.00)	xx	x	na	na
94	1.4, 1.8 (.07)	190, 180 (.78)	250, 160 (.04)	xx	na	x
96	1.1, 1.6 (.01)	220, 220 (.49)	340, 170 (.00)	x	na	na
137	1.2, 2.1 (.00)	288, 185 (.04)	290, 170 (.01)	xx	x	na
143	0.9, 1.6 (.04)	300, 200 (.08)	410, 200 (.01)	na	na	na
147	1.4, 1.3 (.78)	160, 220 (.25)	240, 200 (.28)	240, 200, (.28)	na	na
Pooled Sample	1.3, 1.6 (.00)	250, 200 (.00)	280, 190 (.00)	170, 180 (.69)		

^a x = no telemetry points within 500 m of road

^b na = no road of this ADT class within home range

^c xx = < 5 telemetry points within 500 m of road

Fig 1. Study area with Road network



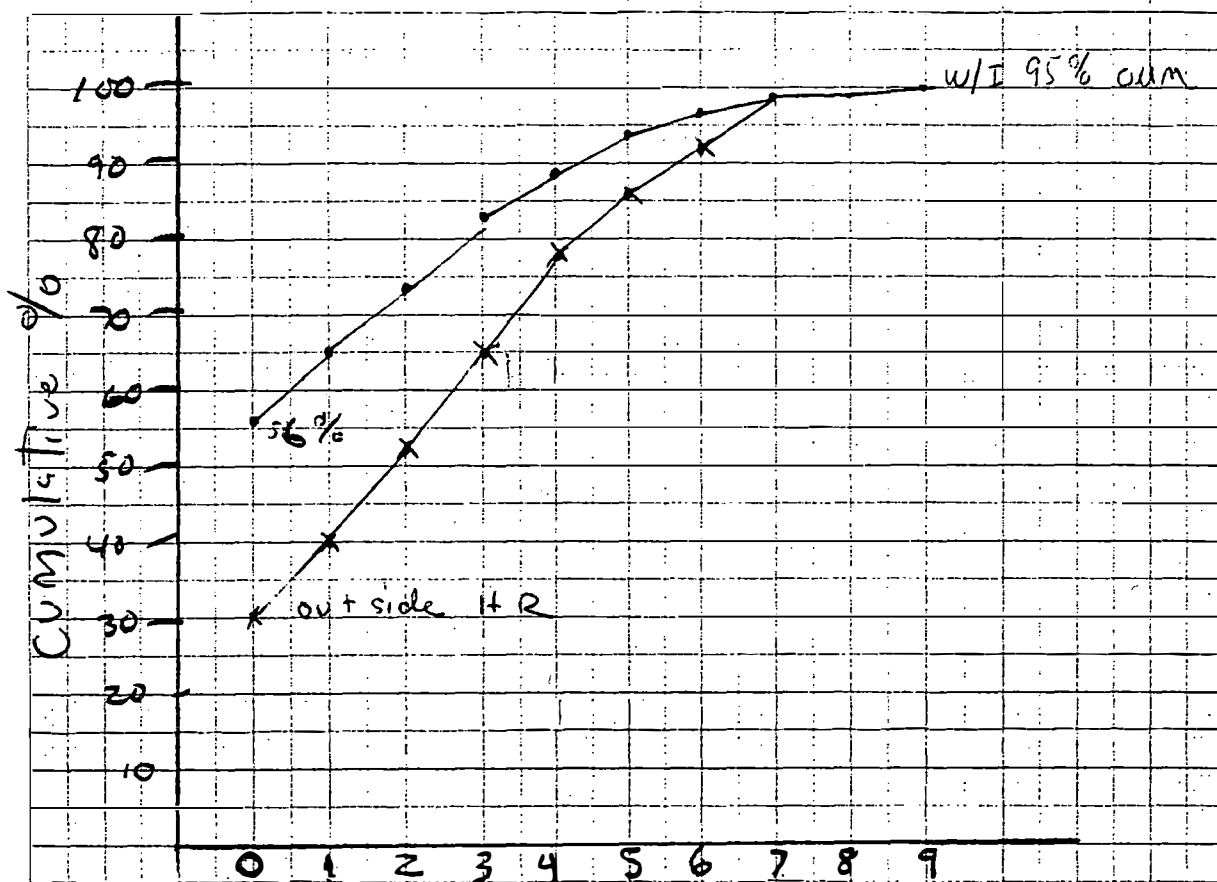
1 Traffic Counter

— approx Boundary of
Composite R&H Range

A Gray-scale study area
with elevation relief

Fig. 2
Fig. 6

Total RD Class
w/I w/o cum 95% hr

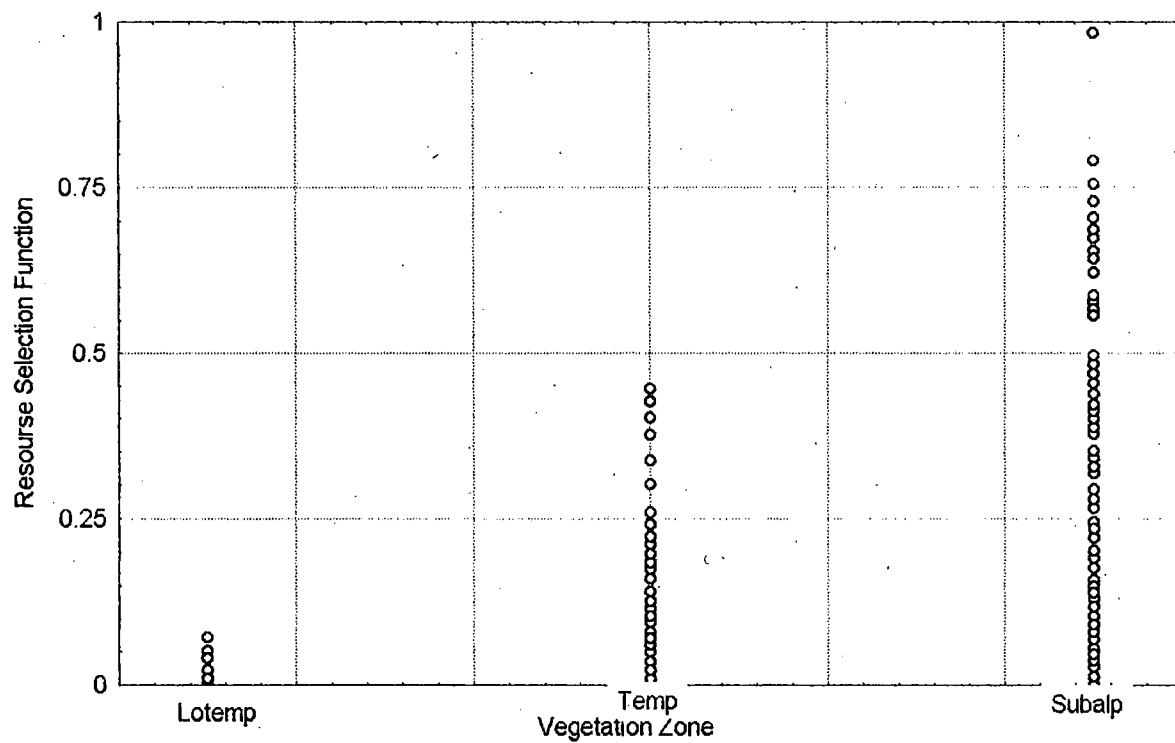


STAT. BASIC STATS	TOTAL_10 (hmos95.sta)	
Value	Count	Cumulative Percent
1.00000	64	58.87
2.00000	73	67.18
3.00000	82	71.21
4.00000	88	78.91
5.00000	92	85.21
6.00000	95	88.69
7.00000	97	94.35
8.00000	98	97.05

STAT. BASIC STATS	TOTAL_10 (hmos95.sta)	
Value	Count	Cumulative Percent
0.00000	730	29.8324
1.00000	256	40.2942
2.00000	294	52.3089
3.00000	315	65.1819
4.00000	317	78.1365
5.00000	201	86.3506
6.00000	170	93.2979
7.00000	80	96.5672
8.00000	35	97.9975
9.00000	49	100.0000
Missing		

Total RD Classes
0.5 km/km2

Fig. 3.



Resource Selection Function

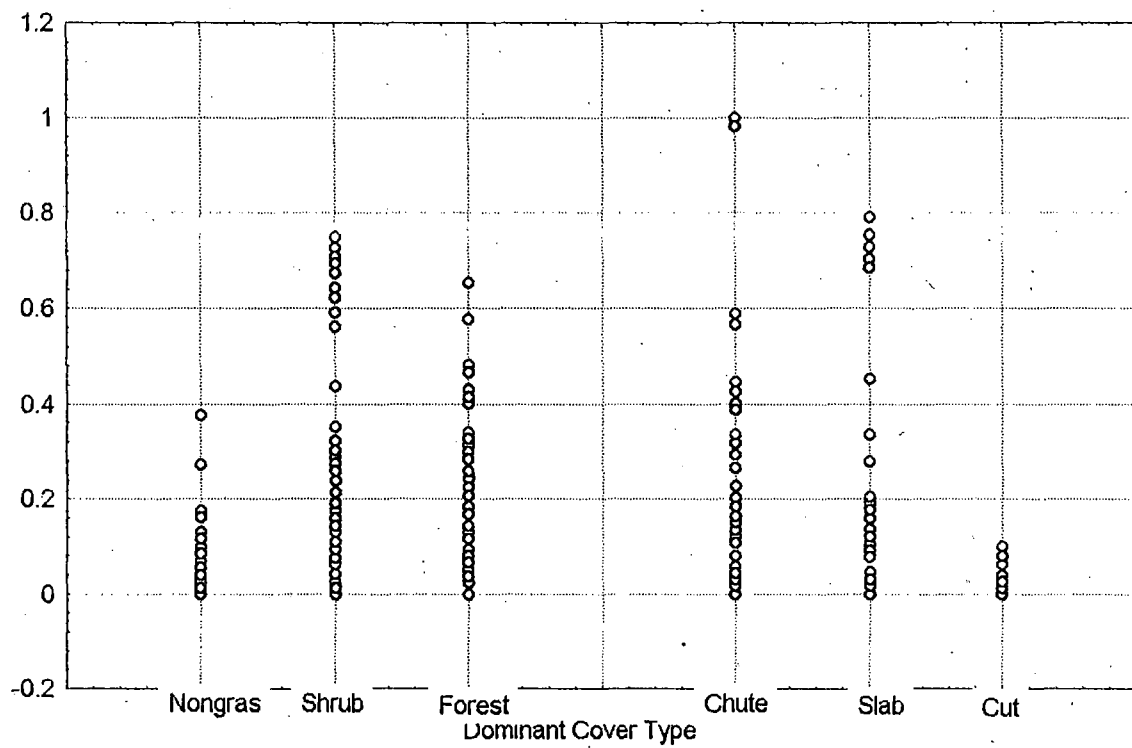


Fig 5

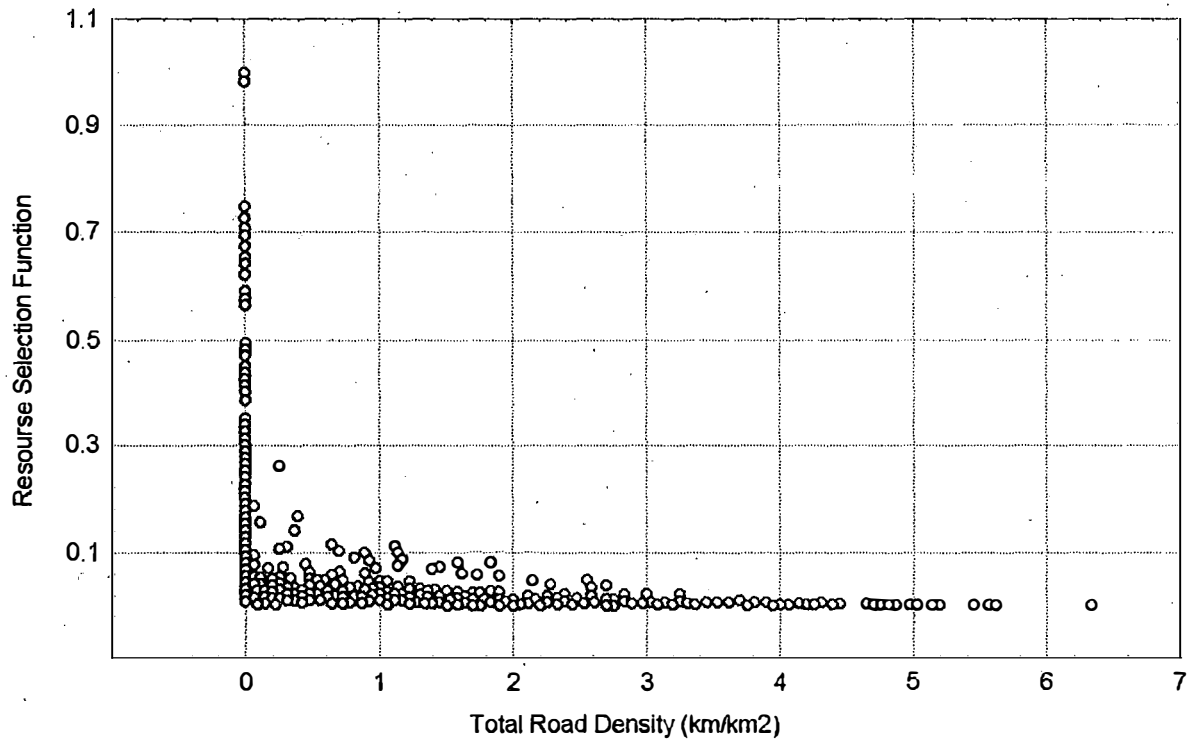


Fig 6.

